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AB Steel slabs containing **C** <0.05, **Si** ≤2.5, **Mn** 0.1-4.0, **S** >0.2 and ≤0.8, **B** >0.004 and <0.08, O >0.008 and ≤0.05, N <0.05 weight%, and balance **Fe** are hot rolled at 1100-1250° and finish temperature ≥1000° and optionally hot rolled in the 2nd stage at 1050-1200° and finish temperature ≥1000° to give free-cutting steels. The steel slabs may also contain **Cu** ≤2.0, **Ni** ≤2.0, **Cr** ≤3.0, **Mo** ≤2.0, **Nb** ≤0.10, W ≤0.1, **V** ≤0.5, P ≤0.2, **Te** ≤0.2, **Se** ≤0.2, Sn ≤0.3, Zr ≤0.2, **Ca** ≤0.02, rare earth metals ≤0.02, Bi ≤0.3, Sb ≤0.2, Co ≤0.1, **Ti** ≤0.3, Mg ≤0.02, Hf ≤0.1, and/or **Al** ≤1.0 weight%. The free-cutting steels show machinability equal to or higher than that of **Pb**-containing free-cutting steels.

PATENT ABSTRACTS OF JAPAN

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(54) METHOD FOR PRODUCING FREE CUTTING STEEL

(57)Abstract:

PROBLEM TO BE SOLVED: To inexpensively produce a free cutting steel which has machinability equal to or above that of a lead free cutting steel as-rolled.

SOLUTION: The steel has a composition containing, by mass, <0.05% C, ≤2.5% Si, 0.1 to 4.0% Mn, >0.2 to 0.8% S, >0.004 to <0.08% B, >0.008 to 0.05% O and <0.05% N, and the balance Fe with inevitable impurities. Further, its hot rolling is performed at the heating temperature of 1,100 to 1,250°C, and at the rolling finishing temperature of ≥1,000°C.

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CLAIMS

[Claim(s)]
[Claim 1] By mass %, less than C:0.05%, below Si:2.5 %, Mn:0.1 - 4.0 %, S: 0.2 % **, below 0.8 %, B:0.004 % **, less than 0.08%, O:0.008 % **, 0.05% or less, and less than N:0.05% are contained. The remainder is the manufacture approach of the free cutting steel characterized by facing the cast piece which becomes the presentation of Fe and an unescapable impurity hot-rolling, heating this cast piece in a 1100-1250-degree C temperature region, and ending rolling in a temperature region 1000 degrees C or more.
[Claim 2] The manufacture approach of the free cutting steel characterized by heating this cast piece in a 1100-1250-degree C temperature region, ending the 1st-step rolling on the occasion of hot rolling of a cast piece in claim 1 in a temperature region 1000 degrees C or more, heating in a further 1050-1200-degree C temperature region, and ending the 2nd-step rolling in a temperature region 1000 degrees C or more.
[Claim 3] The manufacture approach of the free cutting steel characterized by becoming the presentation whose cast piece contains one sort further chosen from from by mass % while of Cu<=2.0% and nickel<=2.0 %, Cr<=3.0 %, Mo<=2.0 %, and Nb<=0.10%, or two sorts or more in claims 1 or 2.
[Claim 4] The manufacture approach of the free cutting steel characterized by becoming the presentation whose cast piece contains one sort further chosen from from among W<=0.1 % and V<=0.5 % by mass %, or two sorts in claims 1, 2, or 3.
[Claim 5] In claims 1, 2, 3, or 4 a cast piece by mass % further P<=0.2 %, Te<=0.2 %, Se<=0.2 %, Sn<=0.3 %, Zr<=0.2 %, The manufacture approach of the free cutting steel characterized by becoming the presentation containing one sort chosen from from among Bi<=0.3 %, Sb<=0.2 %, Co<=0.1 %, and Ti<=0.3 %, or two sorts or more calcium<=0.02% and REM <=0.02%.
[Claim 6] The manufacture approach of a free cutting steel that a cast piece is further characterized by becoming the presentation containing one sort chosen from from among Hf<=0.1 % and aluminum<=1.0 % Mg<=0.02% by mass %, or two sorts or more in either of claims 1-5.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] Especially this invention tends to aim at advantageous improvement in machinability, such as chip processability, or a tool life in cutting about the manufacture approach of a free cutting steel.
[0002]
[Description of the Prior Art] Conventionally, various steel materials, such as calcium deoxidized steel, a tellurium free cutting steel, a selenium free cutting steel, and a bismuth free cutting steel, are developed as the sulfur free cutting steel specified to JIS and leaded carbon steel, or others as a free cutting steel excellent in the machinability and the tool lives at the time of cutting, such as chip processability.
[0003] Especially, leaded carbon steel is excellent in machinability, and moreover, since it is economical as compared with a tellurium, a bismuth, etc., it is used abundantly as a free cutting steel. However, since lead was very harmful to the body, in the manufacture process of not only the manufacture process of steel materials but the machine part using it, it needed the large-scale exhaust air facility, and had a problem also in respect of recycle of steel materials. For this reason, development of lead addition steel and the free cutting steel which has the machinability of equivalent extent was desired from the former, without adding lead.
[0004] The method of improving machinability is proposed by making C in steel exist in JP,50-96416,A as a graphite, and using the notch lubrication action of this graphite for it as what responds to the above-mentioned request, without using lead. However, this approach had left the problem on the need of graphitizing C in steel at the place which whose heat treatment is indispensable and cannot necessarily say it with an economical approach as that pretreatment.
[0005]
[Problem(s) to be Solved by the Invention] Without having been developed in view of the above-mentioned present condition, and using lead, moreover this invention is as [rolling], is excellent in machinability, and aims at proposing the manufacture approach of a new free cutting steel that the free cutting steel which is moreover satisfactory in any way on environmental sanitation can be manufactured economically.
[0006]
[Means for Solving the Problem] Now, artificers did not add lead, but as a result of examining wholeheartedly presentation and the manufacture approach of steel materials that ** is also as [rolling] and has machinability equivalent to lead addition steel, they acquired the knowledge expressed below.
1) By reducing the cementite in steel, tool wear decreases and a tool life improves. The reduction effectiveness of tool wear here becomes remarkable especially by reducing the amount of C to less than [0.05mass%].
[0007] 2) If the amount of C is reduced to less than [0.05mass%], it will be hard to fracture the chip generated by one side, it will become completely, and waste processability will fall. in order to solve this -- (a) B 0.004mass% **, less than [0.08mass%], and N are added in below 0.05mass% -- reaching -- (b) Mn More than 0.1mass% and S 0.2mass% -- exceeding -- and O 0.008mass% -- especially the thing for which two means to exceed and add are taken against coincidence is effective.
[0008] The reason is as follows. Above (b) By performing a quality governing, O in steel combines with Mn and generates MnO. Thereby, on MnO, MnS generates and MnO-MnS compound inclusion is formed. It is hard to carry out the distraction of this MnO-MnS compound inclusion with rolling, and since it exists in the configuration comparatively near a globular form, it acts as a source of stress concentration at the time of cutting. In this case, by adding B in the range of the above (a), B segregates to the interface of MnO-MnS compound inclusion and a host phase, the plastic deformation of MnO-MnS compound inclusion is controlled

further, and generation of the crack by stress concentration operation is promoted. And B and N have the property which is easy to segregate on the rearrangement under organization, are segregated to up to the rearrangement generated to surrounding **** by the stress concentration to MnO-MnS compound inclusion, embrittle ****, and make propagation of the generated crack easy. Furthermore, since BN generated by association of B and N not only has a lubrication action, but acts as a source of stress concentration as known well, it contributes effective in the improvement in a tool life, and improvement in chip fracture nature. as a result of the fracture nature of a chip improving notably according to these operations, also in the low C steel of C<0.05mass%, a fine chip 5mm or less comes to generate [chip die length], and chip processability is markedly alike and improves.

[0009] 3) In addition to the above 1, addition of optimum dose of Mn and B is effective in improvement in a tool life. This reason is that a bainite texture generates during an organization by addition of Mn and B. That is, it is because a bainite texture has a notch effect to a surrounding ferrite when it was hard compared with the ferrite, and is hard to deform in itself and it becomes a source of stress concentration at the time of cutting for this reason, since it has the structure which the cementite when [monotonous] the carbide in a bainite texture has random bearing accumulated, and stress concentration happens, so chip generation becomes easy. According to the above-mentioned operation, when a bainite texture is made to mixture-ize during an organization, the cutting force at the time of cutting falls, and a tool life improves.

[0010] 4) For gestalt control of MnS which affects machinability, it is important to control the hot rolling conditions of steel materials. The stress concentration operation at the time of cutting becomes small by expanding of MnS, and machinability deteriorates. Therefore, it is necessary to make expanding of MnS at the time of hot rolling control for much more improvement in machinability. For that purpose, the heating temperature and the hot rolling conditions at the time of hot rolling are important, and expanding of MnS can be effectively controlled by controlling these conditions appropriately.

[0011] That is, it follows on raising the heating temperature at the time of hot rolling, a part of MnS dissolves, and the particle size of MnS decreases rather than a cast piece phase. When this is hot-rolled, elongatedness of MnS is more smaller than the case of low-temperature heating by reduction in particle size. Moreover, since MnS which once dissolved re-deposits comparatively minutely in the middle of rolling, average expanding extent of MnS of steel materials is controlled as compared with the case of low-temperature heating. As a result of examining the MnS configuration before heating rolling, although MnS was elongated more, it became clear that the configuration of expanding by subsequent rolling is also larger. Moreover, it is the temperature region which MnS elongates most about rolling conditions. It is the range of 900-1000 degrees C, and it became clear that extent of that expanding is small in the temperature region higher than this temperature region or the low temperature region. therefore -- while raising heating temperature -- as a rolling temperature region By avoiding a 900-1000-degree C temperature region, expanding of MnS can be controlled effectively, consequently machinability is boiled markedly and improves. This invention is based on the above-mentioned knowledge.

[0012] That is, the summary configuration of this invention is as follows.

By Mass %, 1. Less Than C:0.05%, Below Si:2.5 %, Mn:0.1 - 4.0 %, S: 0.2 % **, below 0.8 %, B:0.004 % **, less than 0.08%, O:0.008 % **, 0.05% or less, and less than N:0.05% are contained. The remainder is the manufacture approach of the free cutting steel characterized by facing the cast piece which becomes the presentation of Fe and an unescapable impurity hot-rolling, heating this cast piece in a 1100-1250-degree C temperature region, and ending rolling in a temperature region 1000 degrees C or more.

[0013] 2. Manufacture approach of free cutting steel characterized by heating this cast piece in 1100-1250-degree C temperature region, ending the 1st-step rolling on the occasion of hot rolling of cast piece in the above 1 in temperature region 1000 degrees C or more, heating in further 1050-1200-degree C temperature region, and ending the 2nd-step rolling in temperature region 1000 degrees C or more.

[0014] 3. Manufacture approach of free cutting steel characterized by becoming presentation whose cast piece contains one sort further chosen from from by mass % while of Cu<=2.0 %, nickel<=2.0%, and Cr<=3.0 %, Mo<=2.0 %, and Nb<=0.10%, or two sorts or more in the above 1 or 2.

[0015] 4. Manufacture approach of free cutting steel characterized by becoming presentation whose cast piece contains one sort further chosen from from among W<=0.1 % and V<=0.5 % by mass %, or two sorts in the above 1, 2, or 3.

[0016] In above 1, 2, 3, or 4 Cast Piece by Mass % Further 5. P<=0.2 %, Te<=0.2 %, Se<=0.2 %, Sn<=0.3 %, Zr<=0.2 %, The manufacture approach of the free cutting steel characterized by becoming the presentation

containing one sort chosen from from among Bi<=0.3 %, Sb<=0.2 %, Co<=0.1 %, and Ti<=0.3 %, or two sorts or more calcium<=0.02% and REM <=0.02%.
[0017] 6. Manufacture approach of free cutting steel that cast piece is further characterized by becoming presentation containing one sort chosen from from among Hf<=0.1 % and aluminum<=1.0 % Mg<=0.02% by mass %, or two sorts or more in either of the above 1-5.
[0018]
[Embodiment of the Invention] Hereafter, in this invention, the reason which limited the component presentation of a material to the above-mentioned range is explained. In addition, % display of the component presentation shown below is "mass %."
If it adds 0.05% or more, since it adds C less than C:0.05% for reservation on the strength, however the tool wear at the time of cutting will increase and machinability will fall, C is restricted to less than 0.05%. In addition, it may be 0.04% or less preferably.
[0019] Si: It is not only useful as a deoxidizer, but although below 2.5 % Si contributes effective in improvement in the reinforcement by solid solution strengthening, a content Since the fall of a tool life will be caused if it exceeds 2.5%, it is Si. It is necessary to restrict to 2.5% or less. desirable -- It may be 0.6% or less.
[0020] Mn: 0.1 - 4.0 %Mn improves hardenability, promotes generation of a bainite texture, and has the work which raises machinability. Moreover, it is effective also in respect of reservation on the strength. Furthermore, it combines with S, combines with MnS, or O and S, MnO-MnS compound inclusion is generated, and there is also an operation which raises machinability by this. In order to acquire such effectiveness, it is . Since reinforcement will rise and machinability will fall if 4.0 % is exceeded although 0.1% needs to be contained, it is Mn. It limits to the range of 0.1 - 4.0 %. In addition, optimum range It is 0.5-2.5 %.
[0021] S: Although it is the useful element which below 0.2 % ** and 0.8 % S combines with Mn in steel, it serves as MnS, serves as a source of stress concentration at the time of cutting, makes fragmentation of a chip easy, and raises machinability, a content At 0.2% or less, it is deficient in the addition effectiveness, and one side. If it adds exceeding 0.8%, in order to cause the fall of hot-working nature, it limits to the range below 0.2% ** and 0.8 %.
[0022] B: 0.004 % ** and less than 0.08%B are segregated to the interface of MnO-MnS compound inclusion and a host phase, control the plastic deformation of the MnO-MnS compound inclusion in a chip generate time, promote generation of the crack by stress concentration, and are effective in raising chip processability. Moreover, since BN generated by association with N has a lubrication action and the operation as a source of stress concentration, it is effective in raising a tool life and chip fracture nature. Furthermore, hardenability is raised, a bainite texture is generated and, for a certain reason, the effectiveness of raising a tool life is also added positively. However, a content At 0.004% or less, even if it is deficient in the addition effectiveness and adds 0.08% or more on the other hand in it, in order that the effectiveness may be saturated and may cause the rise of component cost rather, B is limited to 0.004 % ** and less than 0.08% of range. in addition -- desirable -- They may be ** and 0.015% or less 0.004%.
[0023] O: 0.008 % ** and 0.05%or less O combine with Mn, and generate MnO. Thereby, on MnO, MnS generates and MnO-MnS compound inclusion is formed. It is hard to carry out the distraction of this MnO-MnS compound inclusion with rolling, and since it exists in the configuration comparatively near a globular form, it acts as a source of stress concentration at the time of cutting. For this reason, it adds positively. However, a content It is O in order for an internal defect to occur in a cast piece, if it is deficient in the addition effectiveness at 0.008% or less and adds exceeding 0.05% on the other hand. It limits to ** and 0.05% or less of range 0.008%. in addition -- desirable -- They are 0.008% ** and 0.03% or less.
[0024] There is a property to be easy to segregate less than N:0.05%N on the rearrangement under organization, it segregates to up to the rearrangement generated to surrounding **** by the stress concentration to the MnO-MnS compound inclusion at the time of cutting, **** is embrittled, and there is an operation which raises chip fracture nature by making propagation of the generated crack easy. Moreover, BN is formed by association with B, and according to this lubrication action of BN, and a stress concentration operation, in order to contribute effective in improvement in a tool life and chip fracture nature, it adds positively. However, since the internal defect and surface crack of a cast piece will occur if a content becomes 0.05% or more, N is limited to less than 0.05%.
[0025] As mentioned above, although the fundamental component was explained, in this invention, much more improvement in machinability or reinforcement can be aimed at by adding the following above-mentioned

components other than a fundamental component. First, in order to raise hardenability, to make a bainite texture generate, and to raise machinability and to raise reinforcement, one sort chosen from from among Cu, nickel, Cr, and Mo and Nb or two sorts or more can be added.

[0026] Cu<=2.0 %Cu raises hardenability, and it can be added in order to secure the improvement in machinability and reinforcement by bainite texture generation. However, a content If it exceeds 2.0%, since reinforcement will rise too much and machinability not only falls, but it will serve as cost quantity, Cu is made to contain below by 2.0 %. especially -- desirable -- It is 1.0% or less.

[0027] nickel<=2.0 %nickel can be added for the improvement in the machinability by the bainite texture generation by the improvement in hardenability, and reservation on the strength. However, since reinforcement rises too much and it not only attaches at an expensive price, but it causes the fall of machinability, superfluous addition is nickel. It is made to contain at 2.0% or less. especially -- suitable -- It is 1.0% or less.

[0028] Cr<=3.0 %Cr is a useful element which is made to promote generation of a bainite texture, as a result raises machinability and reinforcement by improvement in hardenability. However, if it adds exceeding 3.0 %, since not only machinability falls, but reinforcement will rise too much and component cost will go up, it is Cr. It is made to contain at 3.0% or less. in addition -- desirable -- It is 1.5% or less.

[0029] Mo<=2.0 %Mo can be added for the improvement in the machinability by the bainite texture generation by the improvement in hardenability, and reservation on the strength. However, since it not only attaches at an expensive price, but reinforcement rises too much and machinability falls, superfluous addition is Mo. It is made to contain at 2.0% or less. especially -- suitable -- It is 1.0% or less.

[0030] Nb<=0.10%Nb raises hardenability, and it can be added in order to secure the improvement in machinability and reinforcement by bainite texture generation. However, since reinforcement rises too much and component cost not only goes up, but it causes the fall of machinability when it adds superfluously, Nb is made to contain at 0.10% or less.

[0031] Moreover, in order to aim at improvement in on the strength, one sort chosen from from among W and V or two sorts can be added.

Since machinability will fall if it adds exceeding 0.1 % although it has the improvement operation in on the strength by dissolution, W<=0.1 %W is W. It is made to contain at 0.1% or less.

[0032] Since machinability will fall if it adds exceeding 0.5 % although it is the useful element which raises reinforcement by precipitation strengthening by V (C, N), V<=0.5 %V is V. It is made to contain at 0.5% or less.

[0033] Furthermore, in order to aim at further improvement in machinability, at least one sort chosen from from among P, Te, Se, calcium, REM, Zr, Bi, Sn, Sb, and Co and Ti can be made to contain.

P<=0.2 %P is making propagation of the crack in the generated chip easy, and has the operation which raises chip processability notably. However, since hot-working nature will be reduced if it adds exceeding 0.2 %, it is P. It limits to 0.2% or less.

[0034] Te<=0.2 % and Se<=0.2 % -- Te and Se combine with Mn, respectively, form MnTe and MnSe, and when this acts as a chip breaker, they improve machinability. However, also any Since effectiveness will be saturated upwards and the rise of component cost will be caused if it adds exceeding 0.2%, it is each. It is made to contain at 0.2% or less.

[0035] calcium<=0.02% and REM <=0.02%, each of Zr<=0.2 %calcium, and REM and Zr form a sulfide with MnS, and when this acts as a chip breaker, they improve machinability. However, even if it adds exceeding calcium:0.02%, REM:0.02%, and Zr:0.2 %, when effectiveness is saturated, in order to cause the rise of component cost, all are made to contain in the above-mentioned range.

[0036] According to melting at the time of cutting, lubrication, and an embrittlement operation, since Bi<=0.3 %Bi raises machinability, it can be added for this purpose. However, since the rise of about [that effectiveness is saturated] and component cost is caused even if it adds exceeding 0.3 %, it is Bi. It is made to contain at 0.3% or less.

[0037] Each of Sn<=0.3 %, Sb<=0.2 %, and Co<=0.1 %Sn, and Sb(s) and Co(es) are elements which raise machinability according to an embrittlement operation. However, since cost goes up when effectiveness is saturated and it becomes disadvantageous economically even if it adds exceeding Sn:0.3 %, Sb:0.2 %, and Co:0.1 %, all are made to contain in the above-mentioned range.

[0038] Ti<=0.3 %Ti generates TiS and (Mn, Ti) S, serves as a source of stress concentration in a chip, and has the operation which raises chip processability. However, if it adds exceeding 0.3 %, since big and rough TiN

will deposit, the tool wear at the time of cutting will increase and machinability will fall, it is Ti. It is made to contain at 0.3% or less. In addition, an optimum range is 0.01% or less.
[0039] Mg<=0.02% and Hf<=0.1 % -- since Mg and Hf are effective in becoming a source of stress concentration and improving machinability while they are deoxidation elements, respectively, it can add. However, since component cost will go up when the above-mentioned effectiveness is saturated if it adds superfluously, as an addition, it restricts to the above-mentioned range, respectively.
[0040] aluminum<=1.0 %aluminum is an element effective in the strong reservation and the deoxidation by solid solution strengthening. Moreover, it is an oxide. While it is effective in aluminum 2O3 acting as a source of stress concentration at the time of cutting, and improving machinability, since an oxide is hard, there is also an operation which promotes tool wear. Therefore, when using the effectiveness as solid solution strengthening and a source of stress concentration, it can add. However, since the tool wear facilitatory effect by the hard oxide not only becomes remarkable, but will serve as a cost rise if it adds exceeding 1.0 %, it is aluminum. It is made to contain at 1.0% or less. In addition, it may be less than 0.02% preferably.
[0041] In addition, although Pb is not fundamentally added from the main point in this invention, this does not mean that it cannot add technically. That is, the addition will not be barred if what is necessary is to take only a free-machining field into consideration. However, even if it is this case, it is the field of environmental sanitation to an addition. It is desirable to control to extent 0.2% or less.
[0042] Next, the suitable manufacture conditions of this invention are explained. By this invention, in order to control expanding of MnS, the heating temperature and the rolling conditions at the time of hot rolling are specified. First, MnS does not dissolve at all, but at the temperature of less than 1100 degrees C, making heating temperature at the time of hot rolling into 1100-1250 degrees C will be rolled out, while it has been big and rough MnS at the time of casting, and it is because expanding is remarkable. On the other hand, it may be 1250 degrees C or less because hot rolling becomes difficult above this temperature, since a grain boundary fuses partially and the deformability between heat falls. Moreover, rolling termination temperature is made into 1000 degrees C or more in the temperature region which is less than this, because expanding of MnS becomes remarkable.
[0043] Moreover, although a cast piece may be fabricated in this invention in the last configuration with two steps of rollings, hot rolling temperature conditions are specified as follows in that case. That is, about the heating temperature and rolling termination temperature in the 1st-step hot rolling, it is the same as the above-mentioned place. Next, since MnS is made detailed by the 1st-step rolling about the hot rolling temperature conditions of the 2nd step, heating temperature can be lowered to 1200 degrees C or less. However, since it will become difficult to maintain consecutive hot rolling temperature at 1000 degrees C or more if heating temperature is less than 1050 degrees C, it is necessary to make heating temperature into 1050-1200 degrees C. Moreover, it is the same as the case of the 1st step that even this 2nd-step hot rolling needs to make rolling termination temperature 1000 degrees C or more.
[0044]
[Example] After ingoting with the converter the steel which becomes the component presentation shown in the example 1 table 1 and using it as the bloom (cast piece) by continuous casting, it considered as diameter:55mm round bar steel under the hot rolling conditions shown in Table 2. The result investigated about the hardness and machinability (the tool life and chip configuration) of a steel bar which were obtained in this way is written together to Table 2. Here, hardness is the path (D) of a steel bar. It measured by load:98.07 N with the Vickers hardness meter using the extracted sample from one fourth of depth locations. Moreover, using the high-speed-steel tool (SKH4), machinability is the conditions of cutting speed:100 m/min and delivery:0.25mm/rev., infeed:2.0mm, and non-lubrication, and the periphery lathe-turning trial estimated it. Furthermore, the total cutting time to full damage estimated the tool life judging.
[0045]
[Table 1]

鋼記号	成分組成 (mass%)								備考
	C	Si	Mn	S	B	N	O	その他	
A	0.015	0.24	2.53	0.30	0.0054	0.0075	0.0221	—	発明例
B	0.012	0.28	1.80	0.27	0.0049	0.0065	0.0281	—	〃
C	0.042	1.45	1.88	0.32	0.0070	0.0098	0.0232	—	〃
D	0.022	0.02	1.52	0.45	0.0058	0.0081	0.0152	P : 0.065, Nb : 0.031	〃
E	0.012	0.37	0.42	0.29	0.0049	0.0067	0.0214	Cu : 0.30, Ni : C.42, Cr : 0.14	〃
F	0.018	0.03	1.65	0.34	0.0048	0.0062	0.0298	Nb : 0.027, Mo : 0.10, P : 0.060	〃
G	0.018	0.15	0.93	0.31	0.0047	0.0062	0.0201	Mo : 0.32, W : 0.13, V : 0.24	〃
H	0.020	0.49	1.77	0.27	0.0124	0.0165	0.0274	Ca : 0.0018, Nb : 0.029, P : 0.055	〃
I	0.024	0.45	1.26	0.30	0.0060	0.0080	0.0113	REM : 0.010, Ca : 0.0013, Nb : 0.025	〃
J	0.013	0.41	1.32	0.28	0.0084	0.0111	0.0270	Te : 0.13, Zr : 0.23	〃
K	0.014	0.39	2.05	0.28	0.0076	0.0106	0.0138	REM : 0.0088	〃
L	0.023	0.44	1.98	0.38	0.0101	0.0140	0.0221	Pb : 0.15, Bi : 0.07	〃
M	0.022	0.33	1.61	0.23	0.0120	0.0167	0.0226	Sn : 0.16	〃
N	0.015	0.54	1.10	0.57	0.0115	0.0157	0.0274	Se : 0.13, Sb : 0.20	〃
O	0.029	1.15	1.87	0.30	0.0101	0.0135	0.0182	Sn : 0.15, Mo : 0.18	〃
P	0.026	0.55	1.01	0.41	0.0078	0.0107	0.0232	Mg : 0.014, Hf : 0.012, Co : 0.05	〃
Q	0.020	0.58	1.91	0.26	0.0001	0.0001	0.0270	—	比較例
R	0.016	2.78	1.54	0.35	0.0084	0.0109	0.0273	—	〃
S	0.058	0.28	1.58	0.30	0.0093	0.0129	0.0155	—	〃
T	0.027	0.42	0.07	0.39	0.0118	0.0160	0.0105	—	〃
U	0.026	0.48	4.59	0.41	0.0090	0.0125	0.0108	—	〃
V	0.012	0.51	2.08	0.15	0.0083	0.0113	0.0217	—	〃
W	0.012	0.53	1.45	0.91	0.0071	0.0094	0.0134	→ 鋳片圧延時割れ発生	〃
X	0.031	0.39	1.16	0.46	0.0095	0.0520	0.0171	—	〃
Y	0.032	0.56	0.99	0.40	0.0072	0.0097	0.0063	—	〃
Z	0.030	0.43	1.73	0.44	0.0096	0.0124	0.0534	→ 鋳片内部欠陥発生	〃
a	0.080	0.02	1.03	0.34	tr	0.0070	0.0151	Pb : 0.30	従来鋼 SUM24L

[0046]
[Table 2]

No.	鋼記号	熱間圧延温度条件		硬さ Hv (1/4D部)	工具寿命 (min)	切りくず形状*	備考
		加熱温度 (℃)	終了温度 (℃)				
1	A	1114	1025	116	26.7	◎	発明例
2	B	1223	1168	119	33.1	◎	〃
3	C	1193	1136	120	28.3	◎	〃
4	D	1214	1121	116	32.6	◎	〃
5	E	1204	1114	121	32.3	◎	〃
6	F	1106	1029	119	32.9	◎	〃
7	G	1193	1113	115	30.4	◎	〃
8	H	1244	1186	114	28.6	◎	〃
9	I	1206	1123	115	27.8	◎	〃
10	J	1229	1132	120	27.5	◎	〃
11	K	1141	1063	116	29.3	◎	〃
12	L	1118	1060	120	27.3	◎	〃
13	M	1105	1018	117	30.3	◎	〃
14	N	1110	1014	119	29.6	◎	〃
15	O	1224	1128	118	26.8	◎	〃
16	P	1210	1145	115	33.0	◎	〃
17	A	1059	962	120	13.7	×	比較例
18	Q	1205	1129	117	13.3	×	〃
19	R	1239	1164	118	13.6	○	〃
20	S	1173	1104	120	13.2	◎	〃
21	T	1199	1113	117	13.0	×	〃
22	U	1165	1086	189	7.9	◎	〃
23	V	1115	1055	116	13.2	△	〃
24	W	1249	1160	—	—	—	〃
25	X	1192	1129	119	13.0	◎	〃
26	Y	1244	1152	119	13.6	×	〃
27	Z	—	—	—	—	—	〃
28	a	—	—	126	16.5	◎	従来鋼 SUM24L

*切りくず形状 ◎：細かい切りくず（長さ≦5mm）
○：細かい切りくずの中に中位の切りくず（5mm＜長さ≦20mm）
△：中位の切りくずの中に長い切りくず（長さ＞20mm）発生
×：長い切りくず（長さ＞20mm）

[0047] The outstanding tool life of 26.7 - 33.1 min in each of examples of invention of No.1-16 is acquired as shown in Table 2. this -- No.28 Even if compared with 16.5 min of conventional lead addition non-heat-treated steel (JIS SUM24L), it is the life which was markedly alike and was excellent. Moreover, the good chip with as fine die length as 5mm or less was obtained by each also about the chip configuration, and the example of invention of chip processability was also very good. On the other hand, No.17 among the examples of a comparison of No.17-27 Since hot rolling temperature conditions have separated from the proper range of this invention, the tool life and the chip configuration are getting worse. No.18 In order that ** and B may not fulfill the minimum of this invention, the chip configuration and the tool life are getting worse. No.19 Since ** and Si are over the upper limit of this invention, the tool life is falling. No.20 Since ** and C are over the upper limit of this invention, the tool life is falling below to one half compared with the example of invention. No.21 In order that ** and Mn may not fulfill the minimum of this invention, a tool life falls and the chip configuration is also getting worse. No.22 ** and since Mn exceeded the upper limit of this invention conversely, the tool life is falling. No.23 In order that ** and S may not fulfill the minimum of this invention, a tool life falls and the chip configuration is also getting worse. No.24 Since hot tearing arose at the time of rolling since ** and S exceeded the upper limit of this invention, and it was obliged to the termination of rolling, evaluation was impossible. No.25 Since ** and N are over the upper limit of this invention, the tool life is falling. No.26 In order that ** and O may not fulfill the minimum of this invention, a tool life is low and the chip configuration is also getting worse. Since O is over the upper limit of this invention conversely, the internal defect occurred in the cast piece

and No.27 cannot be evaluated.

[0048] After ingoting with the converter the steel which becomes the component presentation shown in the example 2 table 1 and using it as the bloom (cast piece) by continuous casting, it considered as the diameter:35mm steel bar by hot-rolling under the 1st step shown in Table 3, and the 2nd-step hot rolling conditions. The result investigated about the hardness and machinability (the tool life and chip configuration) of a steel bar which were obtained in this way is written together to Table 3. In addition, the evaluation approach of hardness, machinability, and a tool life is the same as that of the case of an example 1.

[0049]

[Table 3]

No.	鋼記号	第1熱間圧延温度条件		第2熱間圧延温度条件		硬さ Hv (1/4D部)	工具寿命 (min)	切りくず形状*	備考
		加熱温度 (℃)	終了温度 (℃)	加熱温度 (℃)	終了温度 (℃)				
1	A	1132	1067	1126	1060	119	28.9	◎	発明例
2	B	1208	1110	1111	1059	118	28.8	◎	〃
3	C	1234	1157	1083	1026	119	27.6	◎	〃
4	D	1142	1080	1075	1021	118	27.6	◎	〃
5	E	1226	1136	1077	1026	117	31.6	◎	〃
6	F	1166	1110	1154	1086	122	27.8	◎	〃
7	G	1258	1174	1091	1036	113	29.5	◎	〃
8	H	1194	1106	1122	1060	119	29.8	◎	〃
9	I	1113	1061	1103	1050	120	33.3	◎	〃
10	J	1237	1163	1120	1068	121	28.4	◎	〃
11	K	1208	1119	1072	1017	119	29.9	◎	〃
12	L	1176	1103	1147	1092	117	27.4	◎	〃
13	M	1229	1161	1133	1083	121	30.1	◎	〃
14	N	1145	1054	1199	1131	117	30.1	◎	〃
15	O	1214	1121	1186	1135	118	30.8	◎	〃
16	P	1155	1058	1182	1120	116	30.2	◎	〃
17	A	1062	938	1123	1052	119	13.0	×	比較例
18	A	1133	1048	1008	929	123	13.7	×	〃
19	Q	1127	1056	1148	1095	119	13.6	×	〃
20	R	1169	1111	1078	1022	116	12.9	○	〃
21	S	1169	1077	1096	1028	117	13.5	◎	〃
22	T	1150	1079	1075	1021	119	13.5	×	〃
23	U	1189	1121	1125	1057	189	7.8	◎	〃
24	V	1135	1078	1147	1091	114	13.3	△	〃
25	W	1226	1161	1164	1112	—	—	—	〃
26	X	1142	1066	1106	1043	119	13.6	◎	〃
27	Y	1168	1069	1128	1073	116	12.8	×	〃
28	Z	—	—	—	—	—	—	—	〃
29	a	—	—	—	—	126	16.5	◎	従来鋼 SUM24L

*切りくず形状　◎：細かい切りくず（長さ≦5mm）
○：細かい切りくずの中に中位の切りくず（5mm＜長さ≦20mm）
△：中位の切りくずの中に長い切りくず（長さ＞20mm）発生
×：長い切りくず（長さ＞20mm）

[0050] the outstanding tool life of 27.4 - 33.3 min acquires each of examples of invention of No.1-16 as shown in Table 3 -- having -- this value -- No.29 It is the life which was markedly alike and was excellent compared with 16.5 min of conventional lead addition non-heat-treated steel (JIS SUM24L). Moreover, the good chip with as fine die length as 5mm or less was obtained by each also about the chip configuration, and the example of invention of chip processability was also very good. On the other hand, No.17 among the examples of a comparison of No.17-28 Since the hot rolling temperature conditions of the 1st step separated from the proper range of this invention, the tool life and the chip configuration have deteriorated. Moreover, No.18 Since the hot rolling temperature conditions of the 2nd step separated from the proper range of this invention, a tool life falls too and the chip configuration is also getting worse. No.19 In order that ** and B may not fulfill the minimum

of this invention, the chip configuration and the tool life are getting worse. No.20 Since ** and Si exceeded the upper limit of this invention, the tool life is falling. No.21 Since ** and C exceeded the upper limit of this invention, the tool life is falling below to one half compared with the example of invention. No.22 In order that ** and Mn may not fulfill the minimum of this invention, a tool life falls and the chip configuration is also getting worse. No.23 ** and since Mn exceeded the upper limit of this invention conversely, the tool life is falling. No.24 In order that ** and S may not fulfill the minimum of this invention, a tool life falls and the chip configuration is also getting worse. No.25 Since hot tearing arose at the time of rolling since ** and S exceeded the upper limit of this invention, and it was obliged to the termination of rolling, evaluation was impossible. No.26 Since ** and N exceeded the upper limit of this invention, the tool life is falling. No.27 In order that ** and O may not fulfill the minimum of this invention, a tool life is low and the chip configuration is also getting worse. No.28 ** and since O exceeded the upper limit of this invention conversely, the internal defect occurred in the cast piece and evaluation was impossible.
[0051]
[Effect of the Invention] In this way, according to this invention, the steel materials with which lead is not added but ** also has a lead addition free cutting steel and the machinability more than equivalent in the condition of a rolling as can be obtained cheaply.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] Especially this invention tends to aim at advantageous improvement in machinability, such as chip processability, or a tool life in cutting about the manufacture approach of a free cutting steel.

[Translation done.]

PRIOR ART

[Description of the Prior Art] Conventionally, various steel materials, such as calcium deoxidized steel, a tellurium free cutting steel, a selenium free cutting steel, and a bismuth free cutting steel, are developed as the sulfur free cutting steel specified to JIS and leaded carbon steel, or others as a free cutting steel excellent in the machinability and the tool lives at the time of cutting, such as chip processability.
[0003] Especially, leaded carbon steel is excellent in machinability, and moreover, since it is economical as compared with a tellurium, a bismuth, etc., it is used abundantly as a free cutting steel. However, since lead was very harmful to the body, in the manufacture process of not only the manufacture process of steel materials but the machine part using it, it needed the large-scale exhaust air facility, and had a problem also in respect of recycle of steel materials. For this reason, development of lead addition steel and the free cutting steel which has the machinability of equivalent extent was desired from the former, without adding lead.
[0004] The method of improving machinability is proposed by making C in steel exist in JP,50-96416,A as a graphite, and using the notch lubrication action of this graphite for it as what responds to the above-mentioned request, without using lead. However, this approach had left the problem on the need of graphitizing C in steel at the place which whose heat treatment is indispensable and cannot necessarily say it with an economical approach as that pretreatment.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] In this way, according to this invention, the steel materials with which lead is not added but ** also has a lead addition free cutting steel and the machinability more than equivalent in the condition of a rolling as can be obtained cheaply.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] Without having been developed in view of the above-mentioned present condition, and using lead, moreover this invention is as [rolling], is excellent in machinability, and aims at proposing the manufacture approach of a new free cutting steel that the free cutting steel which is moreover satisfactory in any way on environmental sanitation can be manufactured economically.

[Translation done.]

MEANS

[Means for Solving the Problem] Now, artificers did not add lead, but as a result of examining wholeheartedly presentation and the manufacture approach of steel materials that ** is also as [rolling] and has machinability equivalent to lead addition steel, they acquired the knowledge expressed below.
1) By reducing the cementite in steel, tool wear decreases and a tool life improves. The reduction effectiveness of tool wear here becomes remarkable especially by reducing the amount of C to less than [0.05mass%].
[0007] 2) If the amount of C is reduced to less than [0.05mass%], it will be hard to fracture the chip generated by one side, it will become completely, and waste processability will fall. in order to solve this -- (a) B 0.004mass% **, less than [0.08mass%], and N are added in below 0.05mass% -- reaching -- (b) Mn More than 0.1mass% and S 0.2mass% -- exceeding -- and O 0.008mass% -- especially the thing for which two means to exceed and add are taken against coincidence is effective.
[0008] The reason is as follows. Above (b) By performing a quality governing, O in steel combines with Mn and generates MnO. Thereby, on MnO, MnS generates and MnO-MnS compound inclusion is formed. It is hard to carry out the distraction of this MnO-MnS compound inclusion with rolling, and since it exists in the configuration comparatively near a globular form, it acts as a source of stress concentration at the time of cutting. In this case, by adding B in the range of the above (a), B segregates to the interface of MnO-MnS compound inclusion and a host phase, the plastic deformation of MnO-MnS compound inclusion is controlled further, and generation of the crack by stress concentration operation is promoted. And B and N have the property which is easy to segregate on the rearrangement under organization, are segregated to up to the rearrangement generated to surrounding **** by the stress concentration to MnO-MnS compound inclusion, embrittle ****, and make propagation of the generated crack easy. Furthermore, since BN generated by association of B and N not only has a lubrication action, but acts as a source of stress concentration as known well, it contributes effective in the improvement in a tool life, and improvement in chip fracture nature. as a result of the fracture nature of a chip improving notably according to these operations, also in the low C steel of C<0.05mass%, a fine chip 5mm or less comes to generate [chip die length], and chip processability is markedly alike and improves.
[0009] 3) In addition to the above 1, addition of optimum dose of Mn and B is effective in improvement in a tool life. This reason is that a bainite texture generates during an organization by addition of Mn and B. That is, it is because a bainite texture has a notch effect to a surrounding ferrite when it was hard compared with the ferrite, and is hard to deform in itself and it becomes a source of stress concentration at the time of cutting for this reason, since it has the structure which the cementite when [monotonous] the carbide in a bainite texture has random bearing accumulated, and stress concentration happens, so chip generation becomes easy. According to the above-mentioned operation, when a bainite texture is made to mixture-ize during an organization, the cutting force at the time of cutting falls, and a tool life improves.
[0010] 4) For gestalt control of MnS which affects machinability, it is important to control the hot rolling conditions of steel materials. The stress concentration operation at the time of cutting becomes small by expanding of MnS, and machinability deteriorates. Therefore, it is necessary to make expanding of MnS at the time of hot rolling control for much more improvement in machinability. For that purpose, the heating temperature and the hot rolling conditions at the time of hot rolling are important, and expanding of MnS can be effectively controlled by controlling these conditions appropriately.
[0011] That is, it follows on raising the heating temperature at the time of hot rolling, a part of MnS dissolves, and the particle size of MnS decreases rather than a cast piece phase. When this is hot-rolled, elongatedness of MnS is more smaller than the case of low-temperature heating by reduction in particle size. Moreover, since

MnS which once dissolved re-deposits comparatively minutely in the middle of rolling, average expanding extent of MnS of steel materials is controlled as compared with the case of low-temperature heating. As a result of examining the MnS configuration before heating rolling, although MnS was elongated more, it became clear that the configuration of expanding by subsequent rolling is also larger. Moreover, it is the temperature region which MnS elongates most about rolling conditions. It is the range of 900-1000 degrees C, and it became clear that extent of that expanding is small in the temperature region higher than this temperature region or the low temperature region. therefore -- while raising heating temperature -- as a rolling temperature region By avoiding a 900-1000-degree C temperature region, expanding of MnS can be controlled effectively, consequently machinability is boiled markedly and improves. This invention is based on the above-mentioned knowledge.
[0012] That is, the summary configuration of this invention is as follows.
By Mass %, 1. Less Than C:0.05%, Below Si:2.5 %, Mn:0.1 - 4.0 %, S: 0.2 % **, below 0.8 %, B:0.004 % **, less than 0.08%, O:0.008 % **, 0.05% or less, and less than N:0.05% are contained. The remainder is the manufacture approach of the free cutting steel characterized by facing the cast piece which becomes the presentation of Fe and an unescapable impurity hot-rolling, heating this cast piece in a 1100-1250-degree C temperature region, and ending rolling in a temperature region 1000 degrees C or more.
[0013] 2. Manufacture approach of free cutting steel characterized by heating this cast piece in 1100-1250-degree C temperature region, ending the 1st-step rolling on the occasion of hot rolling of cast piece in the above 1 in temperature region 1000 degrees C or more, heating in further 1050-1200-degree C temperature region, and ending the 2nd-step rolling in temperature region 1000 degrees C or more.
[0014] 3. Manufacture approach of free cutting steel characterized by becoming presentation whose cast piece contains one sort further chosen from from by mass % while of Cu<=2.0 %, nickel<=2.0%, and Cr<=3.0 %, Mo<=2.0 %, and Nb<=0.10%, or two sorts or more in the above 1 or 2.
[0015] 4. Manufacture approach of free cutting steel characterized by becoming presentation whose cast piece contains one sort further chosen from from among W<=0.1 % and V<=0.5 % by mass %, or two sorts in the above 1, 2, or 3.
[0016] In above 1, 2, 3, or 4 Cast Piece by Mass % Further 5. P<=0.2 %, Te<=0.2 %, Se<=0.2 %, Sn<=0.3 %, Zr<=0.2 %, The manufacture approach of the free cutting steel characterized by becoming the presentation containing one sort chosen from from among Bi<=0.3 %, Sb<=0.2 %, Co<=0.1 %, and Ti<=0.3 %, or two sorts or more calcium<=0.02% and REM <=0.02%.
[0017] 6. Manufacture approach of free cutting steel that cast piece is further characterized by becoming presentation containing one sort chosen from from among Hf<=0.1 % and aluminum<=1.0 % Mg<=0.02% by mass %, or two sorts or more in either of the above 1-5.
[0018]
[Embodiment of the Invention] Hereafter, in this invention, the reason which limited the component presentation of a material to the above-mentioned range is explained. In addition, % display of the component presentation shown below is "mass %."
If it adds 0.05% or more, since it adds C less than C:0.05% for reservation on the strength, however the tool wear at the time of cutting will increase and machinability will fall, C is restricted to less than 0.05%. In addition, it may be 0.04% or less preferably.
[0019] Si: It is not only useful as a deoxidizer, but although below 2.5 % Si contributes effective in improvement in the reinforcement by solid solution strengthening, a content Since the fall of a tool life will be caused if it exceeds 2.5%, it is Si. It is necessary to restrict to 2.5% or less. desirable -- It may be 0.6% or less.
[0020] Mn: 0.1 - 4.0 %Mn improves hardenability, promotes generation of a bainite texture, and has the work which raises machinability. Moreover, it is effective also in respect of reservation on the strength. Furthermore, it combines with S, combines with MnS, or O and S, MnO-MnS compound inclusion is generated, and there is also an operation which raises machinability by this. In order to acquire such effectiveness, it is . Since reinforcement will rise and machinability will fall if 4.0 % is exceeded although 0.1% needs to be contained, it is Mn. It limits to the range of 0.1 - 4.0 %. In addition, optimum range It is 0.5-2.5 %.
[0021] S: Although it is the useful element which below 0.2 % ** and 0.8 % S combines with Mn in steel, it serves as MnS, serves as a source of stress concentration at the time of cutting, makes fragmentation of a chip easy, and raises machinability, a content At 0.2% or less, it is deficient in the addition effectiveness, and one side. If it adds exceeding 0.8%, in order to cause the fall of hot-working nature, it limits to the range below 0.2% ** and 0.8 %.

[0022] B: 0.004 % ** and less than 0.08%B are segregated to the interface of MnO-MnS compound inclusion and a host phase, control the plastic deformation of the MnO-MnS compound inclusion in a chip generate time, promote generation of the crack by stress concentration, and are effective in raising chip processability. Moreover, since BN generated by association with N has a lubrication action and the operation as a source of stress concentration, it is effective in raising a tool life and chip fracture nature. Furthermore, hardenability is raised, a bainite texture is generated and, for a certain reason, the effectiveness of raising a tool life is also added positively. However, a content At 0.004% or less, even if it is deficient in the addition effectiveness and adds 0.08% or more on the other hand in it, in order that the effectiveness may be saturated and may cause the rise of component cost rather, B is limited to 0.004 % ** and less than 0.08% of range. in addition -- desirable -- They may be ** and 0.015% or less 0.004%.
[0023] O: 0.008 % ** and 0.05%or less O combine with Mn, and generate MnO. Thereby, on MnO, MnS generates and MnO-MnS compound inclusion is formed. It is hard to carry out the distraction of this MnO-MnS compound inclusion with rolling, and since it exists in the configuration comparatively near a globular form, it acts as a source of stress concentration at the time of cutting. For this reason, it adds positively. However, a content It is O in order for an internal defect to occur in a cast piece, if it is deficient in the addition effectiveness at 0.008% or less and adds exceeding 0.05% on the other hand. It limits to ** and 0.05% or less of range 0.008%. in addition -- desirable -- They are 0.008% ** and 0.03% or less.
[0024] There is a property to be easy to segregate less than N:0.05%N on the rearrangement under organization, it segregates to up to the rearrangement generated to surrounding **** by the stress concentration to the MnO-MnS compound inclusion at the time of cutting, **** is embrittled, and there is an operation which raises chip fracture nature by making propagation of the generated crack easy. Moreover, BN is formed by association with B, and according to this lubrication action of BN, and a stress concentration operation, in order to contribute effective in improvement in a tool life and chip fracture nature, it adds positively. However, since the internal defect and surface crack of a cast piece will occur if a content becomes 0.05% or more, N is limited to less than 0.05%.
[0025] As mentioned above, although the fundamental component was explained, in this invention, much more improvement in machinability or reinforcement can be aimed at by adding the following above-mentioned components other than a fundamental component. First, in order to raise hardenability, to make a bainite texture generate, and to raise machinability and to raise reinforcement, one sort chosen from from among Cu, nickel, Cr, and Mo and Nb or two sorts or more can be added.
[0026] Cu<=2.0 %Cu raises hardenability, and it can be added in order to secure the improvement in machinability and reinforcement by bainite texture generation. However, a content If it exceeds 2.0%, since reinforcement will rise too much and machinability not only falls, but it will serve as cost quantity, Cu is made to contain below by 2.0 %. especially -- desirable -- It is 1.0% or less.
[0027] nickel<=2.0 %nickel can be added for the improvement in the machinability by the bainite texture generation by the improvement in hardenability, and reservation on the strength. However, since reinforcement rises too much and it not only attaches at an expensive price, but it causes the fall of machinability, superfluous addition is nickel. It is made to contain at 2.0% or less. especially -- suitable -- It is 1.0% or less.
[0028] Cr<=3.0 %Cr is a useful element which is made to promote generation of a bainite texture, as a result raises machinability and reinforcement by improvement in hardenability. However, if it adds exceeding 3.0 %, since not only machinability falls, but reinforcement will rise too much and component cost will go up, it is Cr. It is made to contain at 3.0% or less. in addition -- desirable -- It is 1.5% or less.
[0029] Mo<=2.0 %Mo can be added for the improvement in the machinability by the bainite texture generation by the improvement in hardenability, and reservation on the strength. However, since it not only attaches at an expensive price, but reinforcement rises too much and machinability falls, superfluous addition is Mo. It is made to contain at 2.0% or less. especially -- suitable -- It is 1.0% or less.
[0030] Nb<=0.10%Nb raises hardenability, and it can be added in order to secure the improvement in machinability and reinforcement by bainite texture generation. However, since reinforcement rises too much and component cost not only goes up, but it causes the fall of machinability when it adds superfluously, Nb is made to contain at 0.10% or less.
[0031] Moreover, in order to aim at improvement in on the strength, one sort chosen from from among W and V or two sorts can be added.
Since machinability will fall if it adds exceeding 0.1 % although it has the improvement operation in on the

strength by dissolution, W<=0.1 %W is W. It is made to contain at 0.1% or less.
[0032] Since machinability will fall if it adds exceeding 0.5 % although it is the useful element which raises reinforcement by precipitation strengthening by V (C, N), V<=0.5 %V is V. It is made to contain at 0.5% or less.
[0033] Furthermore, in order to aim at further improvement in machinability, at least one sort chosen from from among P, Te, Se, calcium, REM, Zr, Bi, Sn, Sb, and Co and Ti can be made to contain.
P<=0.2 %P is making propagation of the crack in the generated chip easy, and has the operation which raises chip processability notably. However, since hot-working nature will be reduced if it adds exceeding 0.2 %, it is P. It limits to 0.2% or less.
[0034] Te<=0.2 % and Se<=0.2 % -- Te and Se combine with Mn, respectively, form MnTe and MnSe, and when this acts as a chip breaker, they improve machinability. However, also any Since effectiveness will be saturated upwards and the rise of component cost will be caused if it adds exceeding 0.2%, it is each. It is made to contain at 0.2% or less.
[0035] calcium<=0.02% and REM <=0.02%, each of Zr<=0.2 %calcium, and REM and Zr form a sulfide with MnS, and when this acts as a chip breaker, they improve machinability. However, even if it adds exceeding calcium:0.02%, REM:0.02%, and Zr:0.2 %, when effectiveness is saturated, in order to cause the rise of component cost, all are made to contain in the above-mentioned range.
[0036] According to melting at the time of cutting, lubrication, and an embrittlement operation, since Bi<=0.3 %Bi raises machinability, it can be added for this purpose. However, since the rise of about [that effectiveness is saturated] and component cost is caused even if it adds exceeding 0.3 %, it is Bi. It is made to contain at 0.3% or less.
[0037] Each of Sn<=0.3 %, Sb<=0.2 %, and Co<=0.1 %Sn, and Sb(s) and Co(es) are elements which raise machinability according to an embrittlement operation. However, since cost goes up when effectiveness is saturated and it becomes disadvantageous economically even if it adds exceeding Sn:0.3 %, Sb:0.2 %, and Co:0.1 %, all are made to contain in the above-mentioned range.
[0038] Ti<=0.3 %Ti generates TiS and (Mn, Ti) S, serves as a source of stress concentration in a chip, and has the operation which raises chip processability. However, if it adds exceeding 0.3 %, since big and rough TiN will deposit, the tool wear at the time of cutting will increase and machinability will fall, it is Ti. It is made to contain at 0.3% or less. In addition, an optimum range is 0.01% or less.
[0039] Mg<=0.02% and Hf<=0.1 % -- since Mg and Hf are effective in becoming a source of stress concentration and improving machinability while they are deoxidation elements, respectively, it can add. However, since component cost will go up when the above-mentioned effectiveness is saturated if it adds superfluously, as an addition, it restricts to the above-mentioned range, respectively.
[0040] aluminum<=1.0 %aluminum is an element effective in the strong reservation and the deoxidation by solid solution strengthening. Moreover, it is an oxide. While it is effective in aluminum 2O3 acting as a source of stress concentration at the time of cutting, and improving machinability, since an oxide is hard, there is also an operation which promotes tool wear. Therefore, when using the effectiveness as solid solution strengthening and a source of stress concentration, it can add. However, since the tool wear facilitatory effect by the hard oxide not only becomes remarkable, but will serve as a cost rise if it adds exceeding 1.0 %, it is aluminum. It is made to contain at 1.0% or less. In addition, it may be less than 0.02% preferably.
[0041] In addition, although Pb is not fundamentally added from the main point in this invention, this does not mean that it cannot add technically. That is, the addition will not be barred if what is necessary is to take only a free-machining field into consideration. However, even if it is this case, it is the field of environmental sanitation to an addition. It is desirable to control to extent 0.2% or less.
[0042] Next, the suitable manufacture conditions of this invention are explained. By this invention, in order to control expanding of MnS, the heating temperature and the rolling conditions at the time of hot rolling are specified. First, MnS does not dissolve at all, but at the temperature of less than 1100 degrees C, making heating temperature at the time of hot rolling into 1100-1250 degrees C will be rolled out, while it has been big and rough MnS at the time of casting, and it is because expanding is remarkable. On the other hand, it may be 1250 degrees C or less because hot rolling becomes difficult above this temperature, since a grain boundary fuses partially and the deformability between heat falls. Moreover, rolling termination temperature is made into 1000 degrees C or more in the temperature region which is less than this, because expanding of MnS becomes remarkable.

[0043] Moreover, although a cast piece may be fabricated in this invention in the last configuration with two steps of rollings, hot rolling temperature conditions are specified as follows in that case. That is, about the heating temperature and rolling termination temperature in the 1st-step hot rolling, it is the same as the above-mentioned place. Next, since MnS is made detailed by the 1st-step rolling about the hot rolling temperature conditions of the 2nd step, heating temperature can be lowered to 1200 degrees C or less. However, since it will become difficult to maintain consecutive hot rolling temperature at 1000 degrees C or more if heating temperature is less than 1050 degrees C, it is necessary to make heating temperature into 1050-1200 degrees C. Moreover, it is the same as the case of the 1st step that even this 2nd-step hot rolling needs to make rolling termination temperature 1000 degrees C or more.

[Translation done.]